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Modal Identification Experiment Accommodations Review

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Foreword

The work was sponsored by NASA, Langley Research Center under Contract NAS1-19000 to Lockheed Engineering and Sciences Company, Hampton, Virginia. This work describes accommodations on Space Station Freedom (SSF) and will be revised as MIE accommodations are defined for the International Space Station Alpha (ISSA).

Acknowledgments

Mr. Robert W. Buchan, Langley Research Center, Dr. Hyoung-man Kim and Mr. Ted Bartkowicz, McDonnell Douglas Space Systems Company; and Dr. Zoran N. Martinovic, Analytical Mechanics Associates, Inc. are acknowledged for their contributions in determining the locations for the MIE accelerometers and for their inputs to the overall architecture described in this report.

Table of Contents

Table of Contents (Cont'd)

List of Tables

List of Figures

<u>List of Acronyms</u>

1FT	One Fault Tolerant
2FT	Two Fault Tolerant
A/D	Analog to Digital
BDT	Binary Data Transfer
CR	Change Request
C&TS	Communication and Tracking System
CSCI	Computer Software Configuration Item
D/A	Digital/Analog
DMS	Data Management System
DSAR	Data Storage and Retrival
FDDI	Fiber Distributed Data Interface
FSSR	Flight System Hardware Requirements
GC	Ground Control
GST	Ground Support Team
HCI	Human Computer Interface
H/W	Hardware
I/O	Input/Output
IODB	Input-Output Data Base
ISE	Integrated Station Executive
MIE	Modal Identification Experiment
MDM	Multiplexer/Demultiplexer
MDSSC	McDonnell Douglas Space Systems Company

List of Acronyms (Cont'd)

MPAC	Multi-Purpose Applications Console
MSC	Mobile Servicing Center
MSU	Mass Storage Unit
MT	Mobile Transporter
ORU	Orbital Replacement Unit
PC	Personal Computer
PIT	Pre-Integrated Truss
PHPC	Permanent Human Presence Capability
PSDP	Payload Standard Data Processor
PV	Photo-Voltaic
RAM	Random Access Memory
RODB	Runtime Object Data Base
SCB	Signal Conditioning Box
SDIO	Serial Digital/Input/Output
SDMS	Structural Dynamics Measurement System
SDP	Standard Data Processor
SSF	Space Station Freedom
SSFP	Space Station Freedom Program
SSSAAS	Space Station Science and Applications Advisory Subcommittee
SSRMS	Space Station Remote Manipulator System

STSVC	Standard Services
S/W	Software
TDRSS	Tracking and Data Relay Satellite
TOL	Telemetry Objects Lists
USE	User Support Environment
WP-2	Work Package-2

ABSTRACT

The Modal Identification Experiment (MIE) will monitor the structure of the Space Station Freedom (SSF), and measure its response to a sequence of induced disturbances. The MIE will determine the frequency, damping, and shape of the important modes during the SSF assembly sequence including the Permanently Manned Configuration. This paper decribes the accommodations for the proposed instrumentation, the data processing hardware, and the communications data rates. An overview of the MIE operational modes for measuring SSF acceleration forces with accelerometers is presented. The SSF instrumentation channel allocations and the Data Management System (DMS) services required for MIE are also discussed. Appendix A provides a description of the SSF DMS. The DMS software that supports MIE is described in Appendix B.

I. INTRODUCTION

The MIE is a space flight experiment to characterize the structural dynamics of SSF, to develop on-orbit modal test methods, and to evaluate modeling techniques for large space structures. The flight experiment will be conducted during Station reboost operations and consists of excitation of the structure, data recording, and transmission of acceleration data to the ground. On the ground, data processing and analysis will identify structural modes for verification of analytical structural models. Experiment details are available in References 1, 2, and 3.

The original configuration for modal verification of the truss structure comprised 33 accelerometers and 42 strain gages incorporated in the baseline Station design. The verification requirements were later increased to permit monitoring of additional structures outboard of the alpha joints, and of appendages such as the solar arrays, the thermal radiators, and the pressurized modules. This increased the number of accelerometers for structural verification to 79. The MIE is a technology experiment that requires 17 accelerometers in addtion to the 79 required for verification, a total of 96. The configuration of the 96 accelerometers is identified in the Space Station Freedom Program (SSFP), Level II Change Request (CR) number BB003602. The locations of the accelerometers are given in Figure I-1 and Table I-1.

The MIE instrumentation allocations described herein are a result of criteria developed during the Delta Phase B Concept Study, Reference 1 and through consultation with Dr. Hyoung-Man Kim, McDonnell Douglas Space Systems Company (MDSSC). The following additional criteria were developed to reduce the impact of MDM failures, and to reduce excessive wiring between truss segments. Also, a constraint to use existing SSF MDMs limited the channel selection for MIE. The following groundrules were used for the MDM and SCB channel allocations:

- Distribute accelerometers to multiple MDMs (1 MDM per truss segment).
- Accelerometers on the same bulkhead should go to the same MDM.
- Keep SCBs close to their respective MDMs.

- Have at least one SCB per truss segment.
- Add extra channels to existing MDMs before adding extra MDMs.

I.1 MIE Instrumentation

The data acquisition system for MIE utilizes the baseline SSF instrumentation system complemented with MIE accelerometers and Signal Conditioners. The 96 accelerometer configuration is accommodated using nine MDMs and nine Signal Conditioning Boxes (SCBs). The allocation of accelerometers to MDMs and their corresponding analog channels is shown in Table I-1. Similarly, Table I-2 shows the allocation of the SCB analog channels.

The Sundstrand QA 3000-020 accelerometer has been selected for SSF verification. These accelerometers are capable of one micro-G resolution and are calibrated to provide a full scale output of five volts d.c. at 100 milli-G's. An accelerometer enclosure is provided to increase the life of the accelerometer in a space environment, Reference 4. All accelerometers are of this type and are pre-integrated into the SSF hardware.

The Signal Conditioning Boxes are located near groups of MIE accelerometers and selected MDMs throughout SSF. Typical interconnections are shown in Figure I-2. The SCBs filter and amplify the analog electrical signals from the accelerometers and provide analog output signals compatible with analog MDM Input/Output cards. Each SCB has 21 channels for accelerometer interfaces and 22 channels for SSFP strain gages, Reference 5. The SCBs incorporate variable gain amplifiers to provide on-orbit range selection.

The three MIE accelerometer channels allocated to SCB 9, SSF segment S6, could be connected to SCB 8 on segment S4. This would reduce the number of SCBs to eight, but would require additional electrical interfaces between segments. However, the guidelines for this study were to locate the MDMs and SCBs on the same segment as their associated accelerometers where possible. A McDonnell Douglas subsidiary company will design and fabricate the SCBs for WP2.

The MIE architecture does not require all of the SCB accelerometer channels. Discussions with McDonnell Douglas engineers indicate that it would not be feasible to reduce the number of accelerometer channels in each SCB. Duplicate copies of the SCBs are more cost effective than modifying the design to have fewer channels in each unit.

The SSF MDM locations on the truss segments and the system allocations are shown in Figure I-3. The analog and serial MDM channels for the 96 accelerometer configuration were selected from unused MDM channels and cards. The MDM channel and card allocations used were identified from a McDonnell Douglas SSF MDM data base listing, January 19, 1993. Sufficient analog and serial channels and cards are available for the selected MDMs. The MDM and SCB channels required for SSF structural verification and for MIE are given in Tables I-1 and I-2 respectively, which identify the requirements for each SSF segment. The function of the MDM is to multiplex the analog signals from the SCBs and digitize the signals into 12 bit words. This occurs at a rate of 40 times per second and the data is then routed for data storage and downlinking.

II. MIE OPERATIONAL MODES

Much of the flight hardware and software used for MIE is provided as part of the SSF distributed systems. The command, control, and data processing functions are provided by DMS components, and most of the the accelerometers and signal conditioning functions are part of the Structures and Mechanisms (S&M) system. A modal experiment is conducted by sending commands to the Guidance Navigation Control and Propulsion (GNC&P) system to induce the required structural disturbances, and to the S&M system to control the acquisition of data from the accelerometers. The involvement of these systems can only be invoked by core Station control functions.

Figure II-1 is a diagram showing the hardware and software interfaces for MIE. The highest level of Station control is known as Tier 1, which comprises ground control, the crew, and the Integrated Station Executive (ISE) software. The ISE resides in a Standard Data Processor on-board the SSF and provides functional coordination between the SSF core systems. DMS Standard Services provide the software interface to command the other systems. The S&M system software, Reference 6, that controls the acquisition of data from the accelerometers is the Structural Dynamics and Measurement System (SDMS), which resides in the MDMs. In response to commands from Tier 1 the SDMS provides the range settings (amplifier gains) to the SCB, reads the accelerometer data during aqcuisition, and makes the data available to the SDP via the 1553 local bus. An overview of the SSF software architecture is provided in Appendix B.

For safety reasons the control of the structural excitation can only be through these core systems. However, to accommodate the acceleration measurements a modified version of the SDMS software is proposed for the MIE. This MIE software will reside in the MDM and will produce a smaller data set than would be the case if unmodified software were used. Five operational modes are identified for the MIE system: Initialization and Standby, Sensor Ranging, Accelerometer Data Recording, Data Storage, and Data Downlink.

II.1 Initialization and Standby

The SCB is initialized to its default range settings when power is applied. The MIE software is initialized by the MDM power-on process and specific experiment commands that may be required. Initialization determines which Signal

Conditioning Box MIE is using, and configures internal variables and tables as necessary for the selected accelerometer configuration. After initialization, the software transitions to a Standby state. MIE initialization does not access the SCB because power to the unit is controlled by other software. In all modes, after initialization, the MDM software continually monitors for MIE commands from Tier 1.

II.2 Sensor Ranging

The Range command is used to set the range for a single selected channel. The Range-all command provides ranging of all MIE accelerometers to previously selected values with a single command, and is used after power up of the SCBs. The four MIE range selections are 0-4.17, 0-12.5, 0-33, and 0-100 milli G's. MIE ranging is performed during a pretest in which the structure is briefly excited at levels as close as practical to the experiment test levels. Sensor ranging is accomplished by turning on power to the signal conditioner box, waiting the prescribed warm-up period, recording and telemetering the accelerometer responses to the excitation, plotting the responses (on the ground), determining a proper range factor, issuing range commands as required (for each accelerometer), and repeating the process until proper ranges are established.

II.3 Accelerometer Data Recording

The MIE software, upon receiving a Sensor Record command from Tier 1, reads and makes available to the SDP all selected MIE accelerometer data. Ground Control can specify the repeat cycle and duration for the accelerometer record operation. Measurements are taken at 40 Hz beginning at a time and for a duration specified in the "Record" command. All MIE accelerometer channels are processed in the MDMs as 12 bit A/D values . The digitized data are sent to the core Mass Storage Unit (MSU) or transferred to the SDPs over the 1553B local bus interfaces for direct down link, Figure II-1.

II.3.1 Sensor Data and Data Rates

The 96 servo accelerometers are located through-out the Station truss and sub-systems and measure the acceleration forces during specified MIE tests. The MDMs digitize each accelerometer signal and send the MIE data to the core MSU for temporary storage. The DMS Standard Services software assigns a time tag to each accelerometer data sample. Each sample is digitized to 12 bits and has 4 status bits attached. The resulting 16 bit words then have a 64 bit time tag appended. The data samples are therefore represented as 80 bit words that are aquired at 40 samples per second. An MDM transmitting data from 11 accelerometer channels must send data to the SDP at 35.2 Kbps (11 x 80 x 40). However, the DMS Resource Allocation and Margin Analysis Report, Reference 7, indicates that CPU resources are an issue, particularly when high input/output data rates are used. Further study is required to optimize the use of MDM buffer storage and 1553B local bus traffic.

To mitigate problems of CPU and data bus overloading the following data reduction scenario has been devised. Since each of the 80 bit words in the preceding description contains 64 bits of time data, a major reduction in the data volume can be obtained. To achieve this the number of time tags associated with the data must be reduced by modifying the MDM software. This software, instead of attaching time tags to each data sample, would only attach a single time tag at each acquisition interval for each MDM. For example, in an MDM supporting 11 sensors only 40 time tags per second are generated, whereas if DMS Standard Services were used 440 time tags per second would be generated. This reduces the data rate for each channel to (12+4) x 40 = 640 bps, and for an 11 channel MDM from 35.2 Kbps to (11 x 640) + (40 x 64) = 9.6 Kbps

Once an SDP receives the information from the MDMs or from the MSU over the local bus interfaces, the information is loaded to the Runtime Object Data Base (RODB) and setup for data transfers to the Ground, Figure II-1.

II.4 Data Storage

In the case of the MIE accelerometer data the MDMs send the data to the MSU memory, which then allows data transfers to the SDPs as the local bus traffic permits. The data can then be down linked at any time.

The 96 accelerometers are connected to nine MDMs. Each MDM is required to provide buffer storage for an average of 10-11 sets of accelerometer data, which are generated for a period of approximately 800 seconds before transmittion to the MSU. Digitization of accelerometer data at a 40 Hz sample rate for 800 seconds results in the transfer of about 0.96 MBytes (9.6 Kbps x 800/8) of accelerometer data, status bits and time tags from each MDM to the MSU.

II.5 Downlinking Data

Downlinking of the MIE accelerometer data is accomplished using either the Space Station S-Band or Ku-Band communications link to the ground via the Tracking and Data Relay Satellite System (TDRSS), Figure II-1. It is proposed that the S-Band downlink will be used to transfer the MIE data to the ground. Since the total data from an MIE experiment is approximately 8.6 MBytes (68.8Kbps), data is transferred at a low rate to be compatible with the S-Band data rate of 192 Kbps. When the Ku-Band communications is utilized, MIE data can be sent to the ground at a higher data rate.

III. ISSUES

III.1 Channel Allocations

The increase in the number of accelerometers to 96 was the subject of a pending CR at the time of the Space Station redesign. The CR action was dropped during the transition to the current International Space Station Alpha (ISSA). Consequently, the program baseline requirements still call for only 33 accelerometers for verification. It is important that the Program increase the quantity of accelerometers and allocate instrumentation channels as soon as possible to enable the integration of MIE.

III.2 Waiver to Modify Core MDM Software

The proposed allocation of MDMs includes sharing the use of several MDMs with SSF critical system functions. These MDMs are designated as two-fault tolerant (2FT) in the architecture of the SSF core systems. Two-fault tolerant MDMs require Program approval to include additional software for MIE. Discussions with McDonnell Douglas engineers, Huntington Beach, California indicate that the use of 2FT MDMs may require a waiver to permit modification of the software and sharing of MDM resources.

III.3 Local Bus Traffic

The preliminary assessment indicates that, using DMS Standard Services, the CPU and the 1553B bus are likely to be overloaded when servicing 96 accelerometers at 40 samples per second. The proposed software changes mitigate this problem, but a detailed assessment is required to achieve an optimum solution.

III.4 Software Requirements Changes

The proposed changes to the MDM software (to reduce the data volume and use the MDM memory as a buffer) impact the core software requirements, and will require changes to the Flight System Software Requirements.

III.5 Beta Joint Slip Ring Allocations

Adequate connections are available to transfer data from the PV arrays and outboard truss through the alpha joint (via a core 1553B bus). However, no signal channels are available on the Beta Slip Rings. These channels are required to transfer the signals from accelerometers located on the PV arrays to the SCBs and MDMs located on the outboard truss segments. Discussions with Rocketdyne engineers indicated the following options may be available for SSF to accommodate MIE: 1) Up-grade the Slip Rings. 2) Upgrade each of the three data buses. 3) Upgrade the A/D card in the Electrical Control Unit.

IV. CONCLUSIONS AND RECOMMENDATIONS

The Modal Identification Experiment, using 96 accelerometer measurements for SSF is possible if the use of the nine MDMs and channel allocations can be assured, and if the changes to the MDM and SDP software are allowed. The ability to mask only the data needed for transfers across the 1553B bus for downlinking is the key to MIE implemention. Minimizing bus traffic and the elimination of interference with normal station operating conditions are predicated on the ability for MIE to use multiple MDMs and data masking capabilities.

The baseline instrumentation allocations for 33 accelerometers and 42 strain gages on the truss use two MDMs and two SCBs. The concept selected for MIE uses nine MDMs and SCBs distributed over the Station's truss. This reduces the impact of component failures, the length of cable runs, and the number of electrical interfaces between truss segments.

In the time since the foregoing SSF accommodations were defined the Space Station has been redesigned. To accommodate MIE on the International Space Station Alpha the instrumentation configuration will need to be redefined. This new definition will need to address changes in the Station configuration (particularly the redesigned DMS architecture), and must address the issues stated earlier relating to the interaction between the MIE hardware and software and the Station core systems.

SSF Location	ITS Segment	Accelerometers Required			MDMs**			MDM Analog Channels								
		Truss Verif.	Overall Verif.	Verif. + MIE	Item	New MDM No.	Old MDM No.	1	2	3	4	5	6	7	8	9
								S3	S2	S1	M1	P1	P3	P4	S3	S6
WP2 Truss	S3	9	12	12	1	S3-1	MDM 3-17	12								
PM Stbd Lower	S3	0	3	3		S3-1	MDM 3-17	3								
SARJ OB Bulk	S3	0	4	4		S3-1	MDM 3-17	4								
WP2 Truss	S2	6	7	7	2	ETCS-5	MDM 3-20		7							
GN&C Pallet	S2	0	3	3		ETCS-5	MDM 3-20		3							
WP2 Truss	S1	9	3	6	3	ETCS-1	MDM 3-15			6						
HRS Radiator	S1	0	1	1		ETCS-1	MDM 3-15			1						
WP2 Truss	M1	3	7	7	4	M1-1	MDM 3-33				7					
ESA Module	M1	0	3	3		M1-1	MDM 3-33				3					
HAB Module	M1	0	3	3		M1-1	MDM 3-33				3					
JEM Module	M1	0	3	3		M1-1	MDM 3-33				3					
LAB Module	M1	0	3	3		M1-1	MDM 3-33				3					
WP2 Truss	P1	0	0	0		N/R	N/R									
HRS Radiator	P1	0	0	1	5	ETCS-7	MDM 3-10					1				
WP2 Truss	P2	3	3	3		ETCS-7*	MDM 3-10*					3				
WP2 Truss	P3	3	3	3	6	P3-2	MDM 3-24						3			
PM Port Upper	P3	0	0	3		P3-2	MDM 3-24						3			
SARG OB Bulk	P3	0	0	3		P3-2	MDM 3-24						3			
WP4 Truss	P4	0	3	3	7	PVCU-2A	MDM 4-03							3		
PV PIU	P4	0	0	3		PVCU-2A	MDM 4-03							3		
PV PIL	P4	0	0	3		PVCU-2A	MDM 4-03							3		
EPS	P4	0	0	1		PVCU-2A	MDM 4-03							1		
WP4 Truss	S4	0	8	8	8	PVCU-3A	MDM 4-02								8	
EPS	S4	0	1	1		PVCU-3A	MDM 4-02								1	
PV SIU	S4	0	3	3		PVCU-3A	MDM 4-02								3	
PV SIL	S4	0	3	3		PVCU-3A	MDM 4-02								3	
WP4 Truss	S6	0	3	3	9	PVCU-1B	MDM 4-05									3
TOTAL		33	79	96	9			19	10	7	19	4	9	10	15	3

* MDM No. ETCS-7 is located on the P1 segment.

** One digital channel per MDM for range logic.

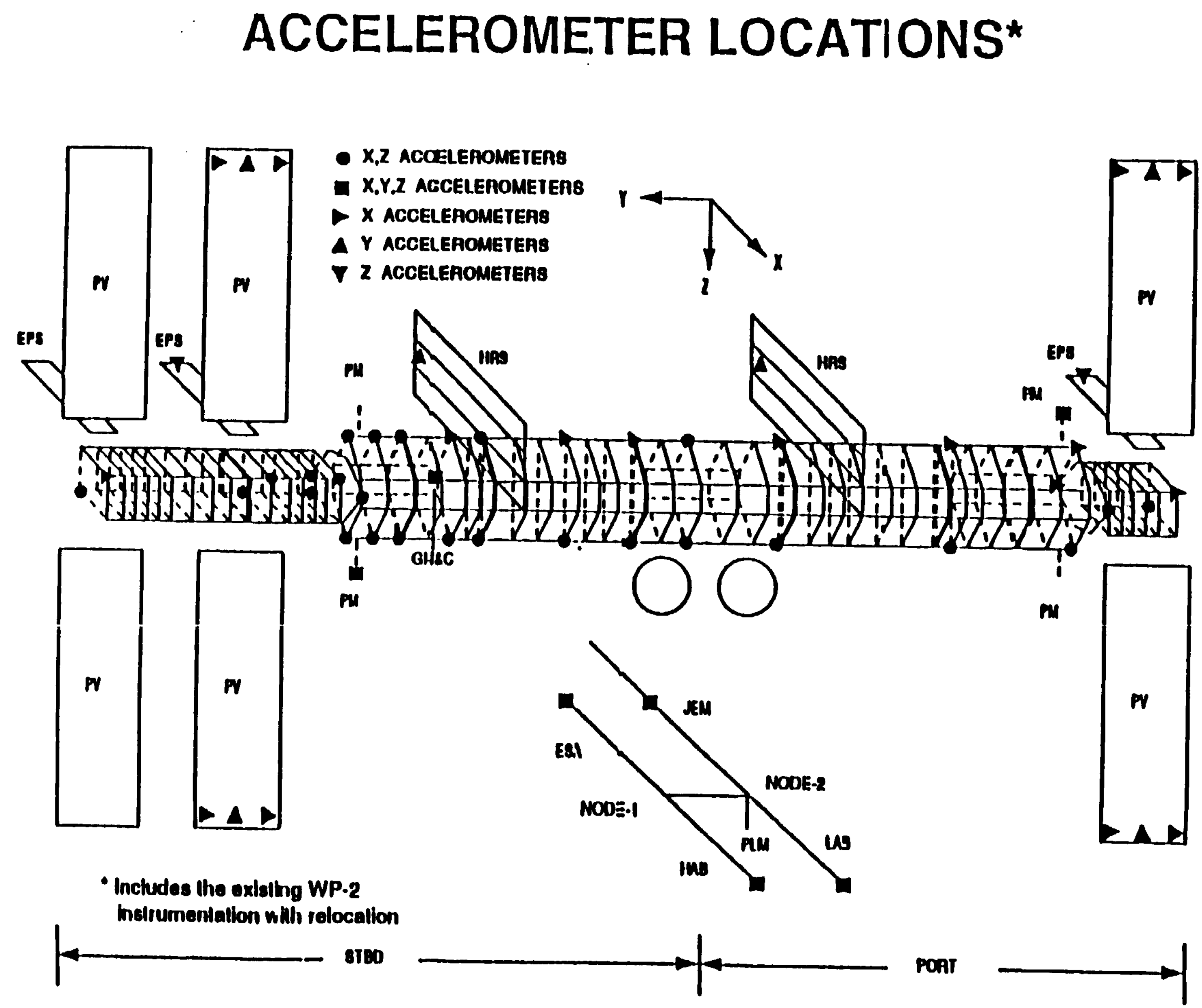
Table I-1. MIE Configuration (96 Accelerometers) MDM Data Channel Allocations

SSF Location	ITS Segment	Accelerometers Required: Truss Verif.	Overall Verif.	Verif. + MIE	MDMs**: Item	New MDM No.	Old MDM No.	SCB Accelerometer Channels: SCB-1	SCB-2	SCB-3	SCB-4	SCB-5	SCB-6	SCB-7	SCB-8	SCB-9
								S3	S2	S1	M1	P1	P3	P4	S4	S6
WP2 Truss	S3	9	12	12	1	S3-1	MDM 3-17	12								
PM Stbd Lower	S3	0	3	3		S3-1	MDM 3-17	3								
SARJ OB Bulk	S3	0	4	4		S3-1	MDM 3-17	4								
WP2 Truss	S2	6	7	7	2	ETCS-5	MDM 3-20		7							
GN&C Pallet	S2	0	3			ETCS-5	MDM 3-20		3							
WP2 Truss	S1	9	3	6	3	ETCS-1	MDM 3-15			6						
HRS Radiator	S1	0	1	1		ETCS-1	MDM 3-15			1						
WP2 Truss	M1	3	7	7	4	M1-1	MDM 3-33				7					
ESA Module	M1	0	3	3		M1-1	MDM 3-33				3					
HAB Module	M1	0	3	3		M1-1	MDM 3-33				3					
JEM Module	M1	0	3	3		M1-1	MDM 3-33				3					
LAB Module	M1	0	3	3		M1-1	MDM 3-33				3					
WP2 Truss	P1	0	0	0		N/R	N/R									
HRS Radiator	P1	0	0	1	5	ETCS-7	MDM 3-10					1				
WP2 Truss	P2	3	3	3		ETCS-7*	MDM 3-10*					3				
WP2 Truss	P3	3	3	3	6	P3-2	MDM 3-24						3			
PM Port Upper	P3	0	0	3		P3-2	MDM 3-24						3			
SARG OB Bulk	P3	0	0	3		P3-2	MDM 3-24						3			
WP4 Truss	P4	0	3	3	7	PVCU-2A	MDM 4-03							3		
PV PIU	P4	0	0	3		PVCU-2A	MDM 4-03							3		
PV PIL	P4	0	0	3		PVCU-2A	MDM 4-03							3		
EPS	P4	0	0	1		PVCU-2A	MDM 4-03							1		
WP4 Truss	S4	0	8	8	8	PVCU-3A	MDM 4-02								8	
EPS	S4	0	1	1		PVCU-3A	MDM 4-02								1	
PV SIU	S4	0	3	3		PVCU-3A	MDM 4-02								3	
PV SIL	S4	0	3	3		PVCU-3A	MDM 4-02								3	
WP4 Truss	S6	0	3	3	9	PVCU-1B	MDM 4-05									3
TOTAL		33	79	96	9			19	10	7	19	4	9	10	15	3

* MDM No. ETCS-7 is located on the P1 segment.

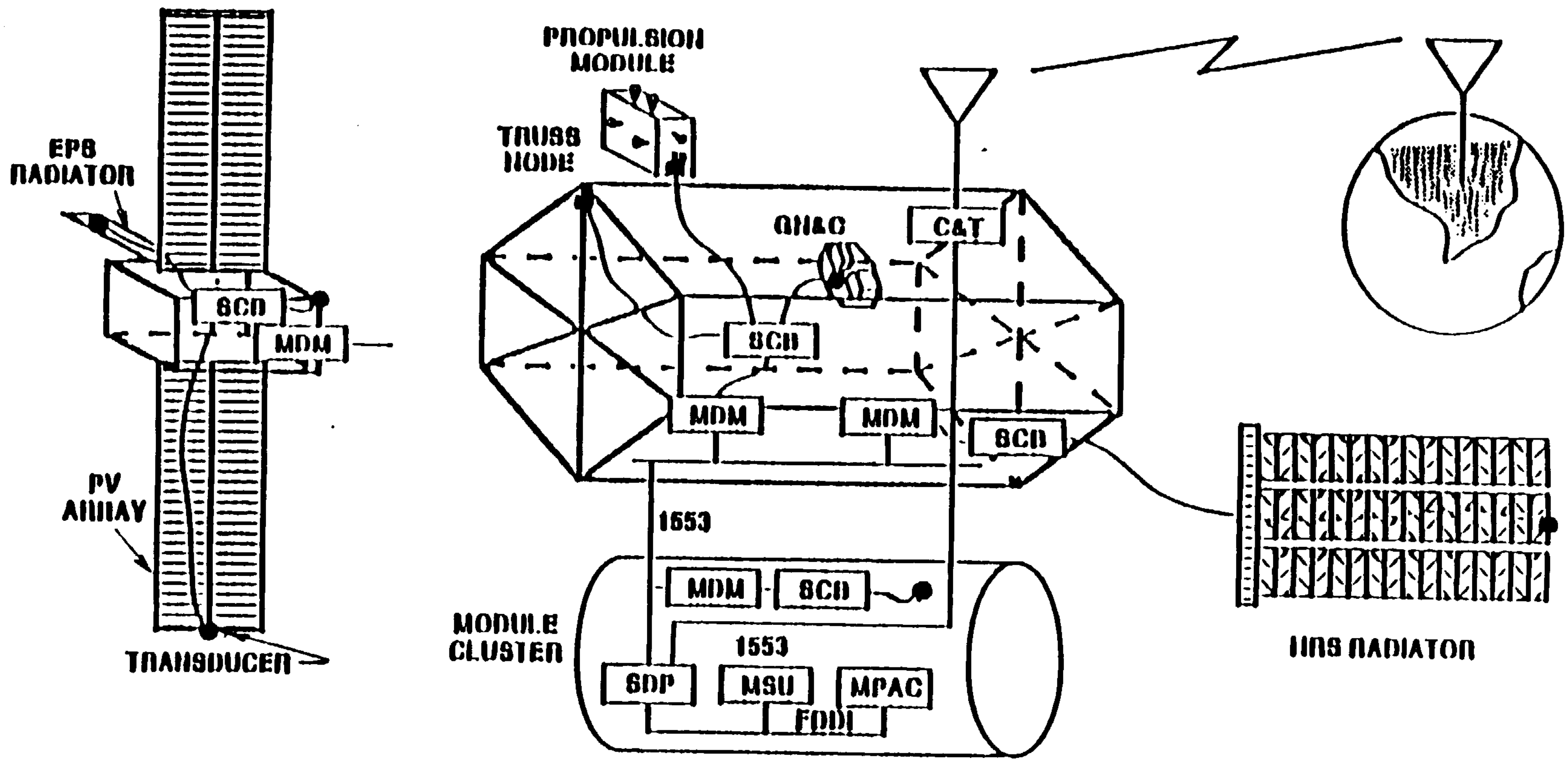
** One digital channel per MDM for range logic.

Table I-2 MIE Configuration (96 Accelerometers) Signal Conditioner Allocations



Source: Reference 1.

Figure I-1. MIE Accelerometer Locations



Source: Reference 4.

I-2 SSF Data Acquisition System-Typical Interconnections.

Source: Presentation to SSSAAS, Dr. V. Whitelow, July 22, 1991.

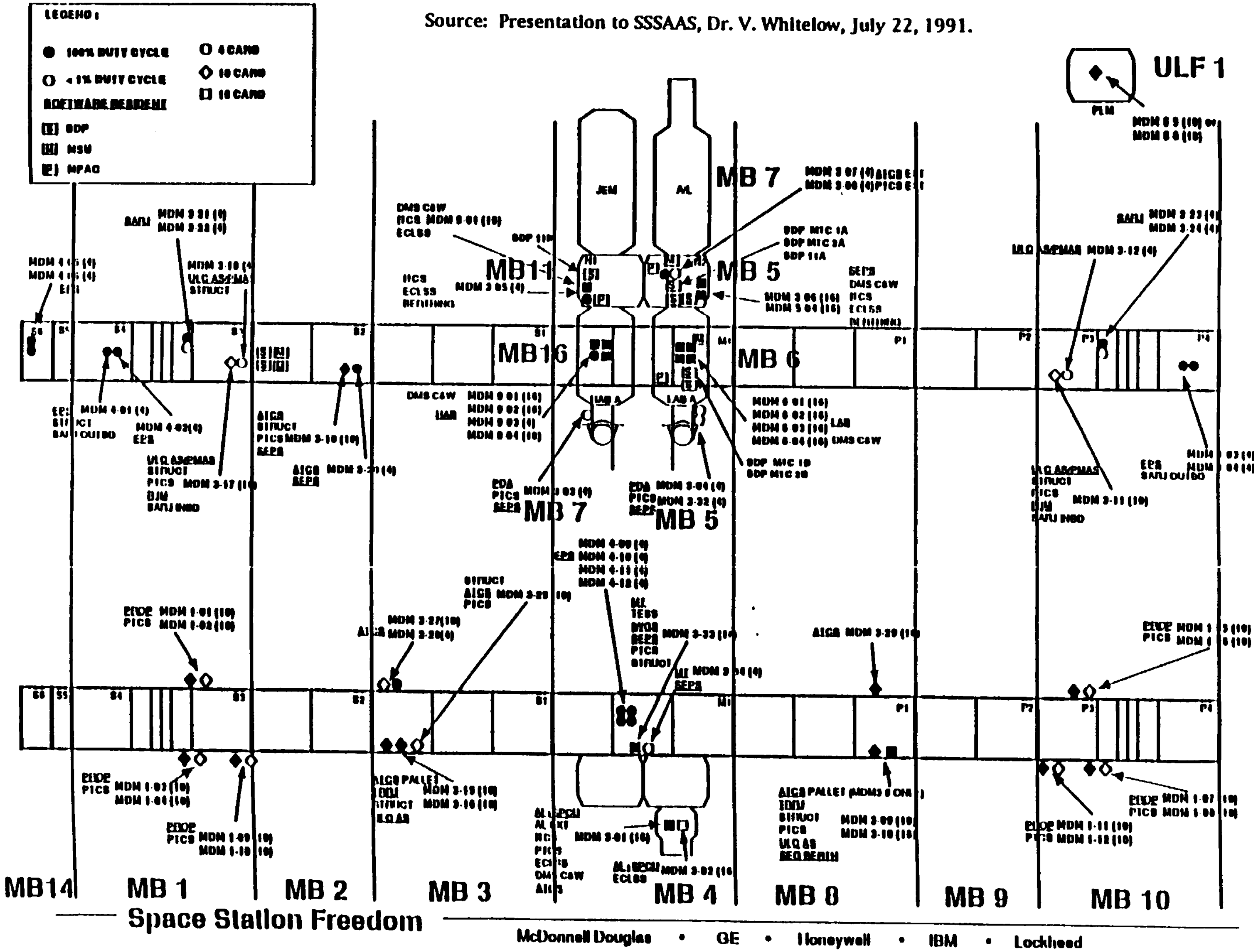


Figure I-3. SSF DMS MDM Locations.

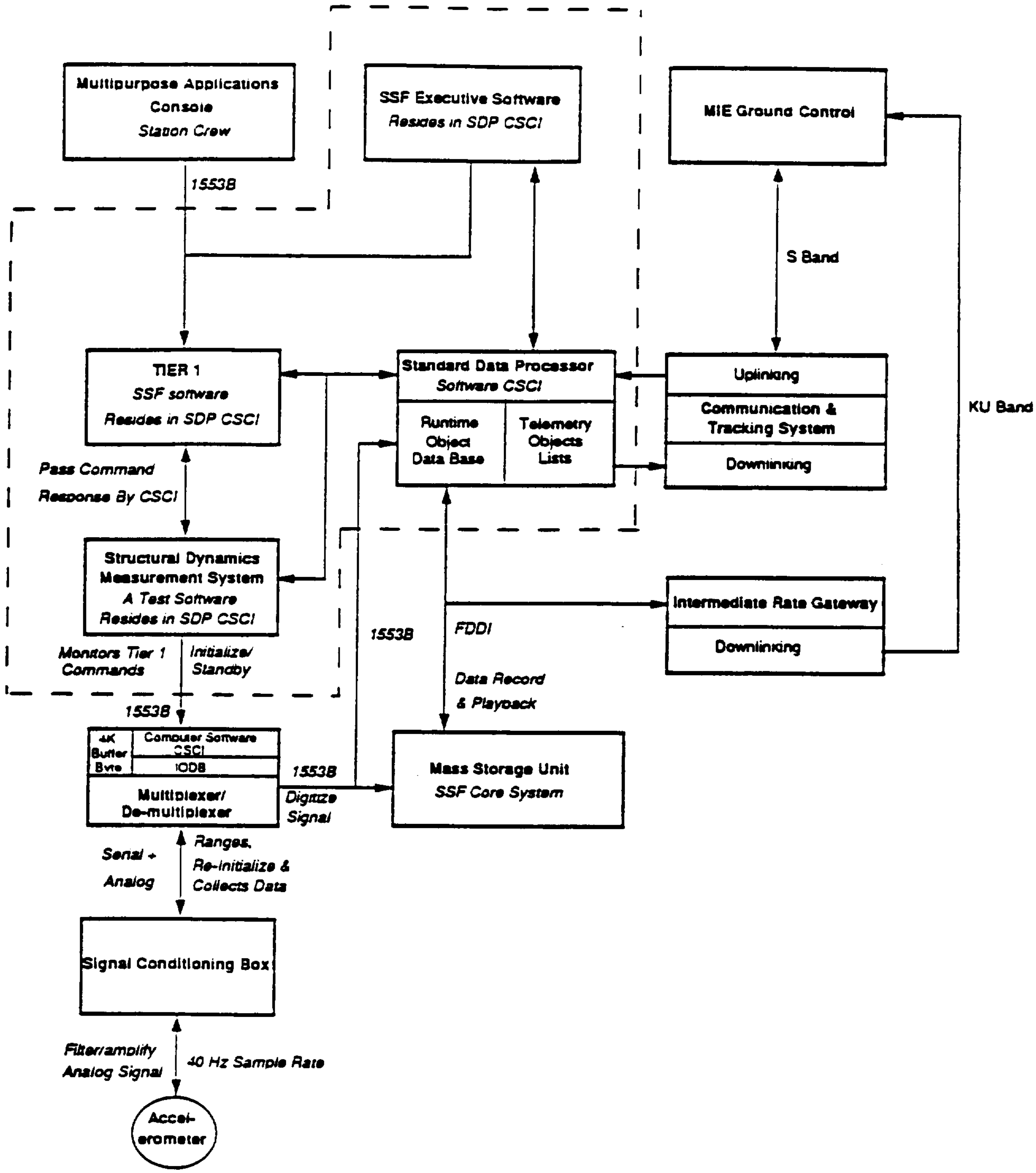


Figure II-1 MIE Data System Interfaces.

APPENDIX A

Baseline SSF Data Management System

The Space Station Freedom Data Management System (DMS) functions as the central nervous system by monitoring all aspects of the Station operation (thermal, environmental, life support, power, navigation and communications). The DMS provides distributed onboard Hardware (H/W) and Software (S/W) resources to support real-time integrated avionics, application data processing, and management operating system. The DMS provides services, process control and data handling of Space Station subsystems and experiments through a network of data processors, work stations, interfaces, data storage & retrieval systems, and runtime data bases. The DMS accomplishes Station operations through interactions with the crew, the ground control center, and the onboard Integrated Station Executive (ISE). The DMS processes and stores all sensor data for the station, presents this information to the crew and ground controllers, executes all control functions, and passes all payload data and controls to the Communication and Tracking Subsystem (C&TS) for relay to the ground. This appendix provides an overview of the DMS. A more detailed description of the SSF DMS is available in the Space Station Freedom Program (SSFP) Engineering Design Council document, Reference 8.

Interfaces provided to support the DMS services include Fiber Distributed Data Interfaces (FDDI), serial Mil-Std 1553B bus interfaces and analog signal interfaces. These interfaces provide connectivity for the Core data networks, Payload data networks, gateways to International data systems and Orbital Replacement Units (ORUs) subsystems.

The DMS is composed of multiple configuration data processors that execute onboard software in a real-time, runtime environment. The ISE coordinates process control and data handling among these data processors, and provides for interaction with the crew, the ground control center, and other resident software services. The current baseline system is minimally one-fault tolerant, whereby there are at least two strings of hardware/software functions to provide redundant backup in cases of failure or inoperability. Some core Station functions of DMS are two-fault tolerant and provide services for those critical functions necessary to maintain station or crew survival.

A.1. Standard Data Processors (SDP)

The primary processors utilized for DMS are the Standard Data Processors (SDPs). There are four SDPs connected together via the Fiber Distributed Data Interface (FDDI) networks, and incorporating separate and duplicate software environments for those functions requiring one or two fault tolerance. All SDPs contain the same network S/W, critical ISE S/W and Runtime Object Data Base (RODB) management S/W. Two of the initial SDPs (out of four) are operating concurrently (partitioned by FT functions), while the other two are either in warm backup mode (on demand functions) or cold start mode (spare- off).

All four SDPs connect to the same FDDI interfaces and serial 1553B interface buses. It is this redundant connectivity and functional partitioning that allows the DMS system to rely on a timeline approach to station operation, while also relying on other Station processors to provide data processing, control and ORU operation. Figure A-1 is a block diagram of the SDP configuration for the baseline Space Station.

The four SDPs provide the runtime operation and coordination of data necessary to perform Station functions, station reporting and network services. Software utilized by the SDPs is ADA based and connects to multiple 1553B busses for interaction with subsystems and ORUs. The FDDI is used for connection to Multi-Purpose Application Consoles (MPACs), Mass Storage devices (MSUs), bridges to Payload networks, and a gateway to the International data system. A dual FDDI ring network (counter-rotating) is incorporated to provide a high speed data interface (> 10 Mbps) between the SDPs and the other processing devices on the FDDI network.

The serial 1553B interfaces allow medium speed (1 Mbps) data transfers between the SDPs, the Multiplexer/Demultiplexers (MDMs), and the subsystem ORUs. The SDPs also coordinate data transfers with the Communications and Tracking Subsystem for Command and Control data uplink, telemetry data downlink, health and status data reporting, and payload (low rate) data reporting.

A fifth SDP exists on the core network and is responsible for services and functions pertaining to the Mobile Servicing Center (MSC), which essentially is the Mobile Transporter and SSRMS systems.

A.2. Multiplexer/ Demultiplexer (MDM)

The Multiplexer/Demultiplexer (MDM) is a microprocessor based (Intel 386 SX) data processor that is responsible for providing data services to sensors and effectors throughout the Station. The MDMs are located strategically along the Truss structure, and throughout the elements, modules and systems. The MDMs, while running their own internal software processing and data functions, routinely receive commands from the SDPs for function, control or data gathering processes. Each MDM connects to the network of SDPs through a series of serial bus connections (1553B) and communicates with the SDP. Some MDMs require a higher frequency of communication with the SDPs than others, a term usually referred to as duty cycle.

In the baseline system, there will be a total of 66 MDMs located throughout the station in its Permanently Manned Configuration (PMC). Each MDM has unique software operations and hardware connections dependent on its subsystem functions. The basic MDM configuration includes a back plane technology for interconnecting PC boards, a processor section, a network interface section, and a section (I/O channels) devoted to reading analog sensors and controlling end effectors. Depending upon the location and use of the MDM, additional software memory, RAM and I/O channels may be required to perform the necessary functions (i.e. different MDM configurations). The processor section is responsible for running the embedded software, updating the I/O database, data processing/formatting and overall control of the other sections. The interface section provides connectivity to the SDPs via serial 1553B interfaces and also controls separate serial interfaces (RS-422) for additional functions related to sensor/control devices or ORUs. The I/O section is responsible for connecting to 32/64 analog channels of inputs or outputs which directly utilize sensors or end effectors, and for performing A/D and D/A conversions. These connections provide the necessary data for station sensor/effector operation, and rely on data processing in the MDM for data communications with the SDPs and Station operating system.

MDMs also are connected to signal conditioning boxes, which are used to range the analog sensor signals to the required levels for the analog I/O channels on the MDMs. The signal conditioning box is controlled by the MDM(s) via RS-422 serial interface connections. A diagram of the baseline MDMs and their locations are shown in Figure A-2. Some of the MDMs have I/O channels that are not allocated for use by the baseline Station program, and therefore may be targeted for use or terminated.

A.3. Multi-Purpose Application Console (MPAC)

The MPAC is a computer with an embedded processor that provides specialized hardware control and data processing resources for the NASA Space Station workstations. The MPAC is the electronic core of hardware components that comprises crew workstation system and provides the Human-Computer Interface (HCI) to the DMS network.

Connected via dual ring, counter-rotating FFDI networks, the MPAC contains an SDP architecture (use of an Embedded Data Processor). The processors host the User Support Environment (USE) software and provide the services and functions that allow HCI connection to both the DMS core network and the payload network. The MPAC is supplied with video display monitors, a keyboard, connections to a printer, and hand controllers to provide complete interaction with the DMS networks via operator controls. Figure A-3 shows the interconnection of the MPAC with the major DMS components.

A.4. Mass Storage Units (MSU)

The Mass Storage Unit is a secondary memory device used for bulk storage of Space Station information. The MSU mass storage media is a direct access, nonvolatile, magnetic disk memory, which provides up to 320 megabytes of formatted data. The MSU contains an SDP architecture (use of Embedded Data Processor) which provides the processing, instructions, memory, and input/output capabilities to receive input information, and to manipulate and process the information for storage. The MSU software also utilizes a set of USE software functions and services that provide links to the DMS core and payload networks.

The MSU interfaces with the FDDI network and 1553B local buses, and can communicate with SDPs, MPACs, MDMs, and other ORUs. Figure A-3 shows the FDDI interfaces.

A.5. Payload Standard Data Processor

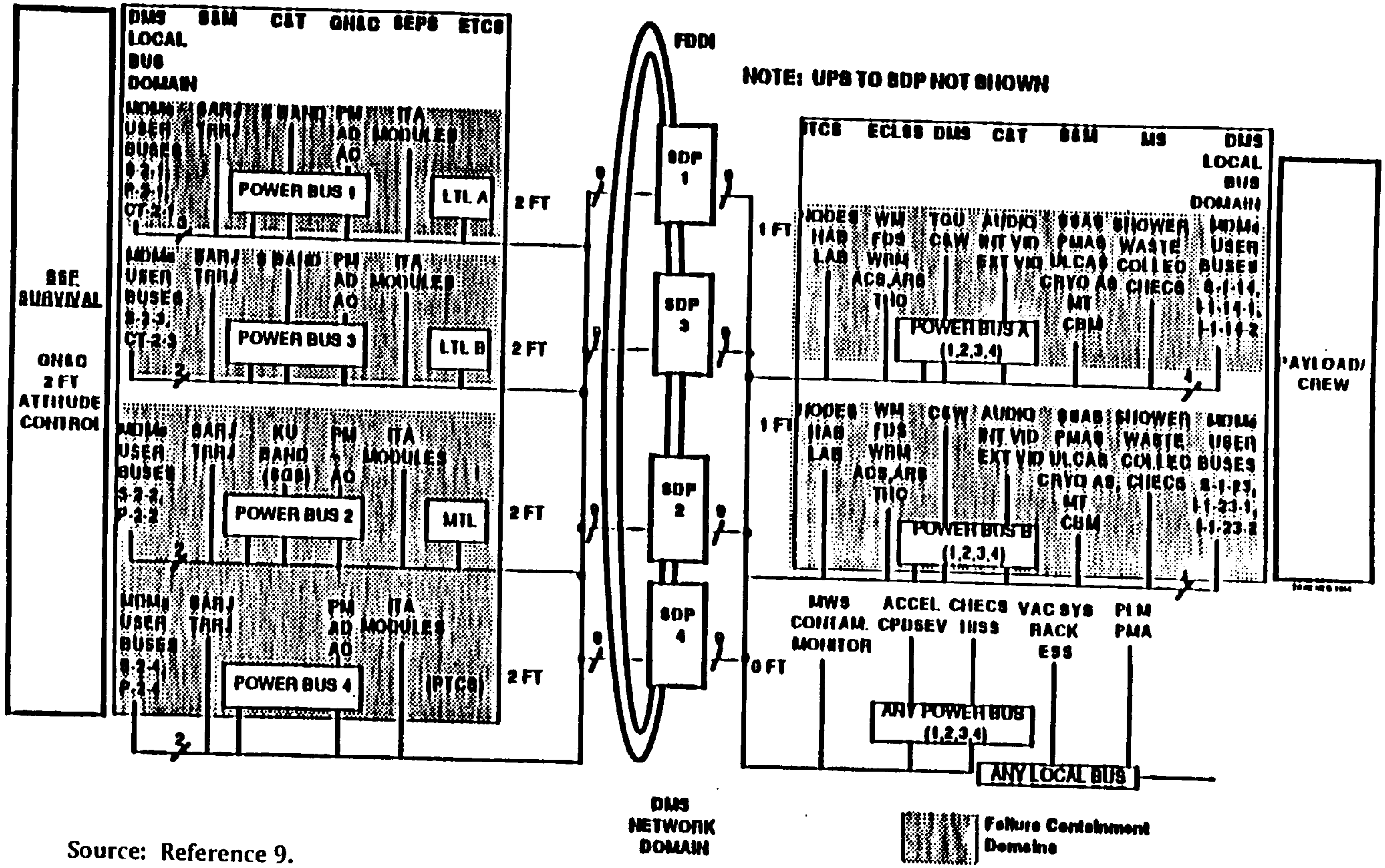
The Payload Standard Data Processor (PSDP) provides connectivity to the Payload FDDI network at the rack level and can provide data processing resources to support control and management of onboard payload operations, general data processing, memory, and I/O capabilities. The PSDP is configured with an SDP architecture and hosts specialized software to receive input information. It processes and manipulates the information under the direction of its internal stored program, provides processed results to users, and stores payload data. The payload FDDI connects to the DMS Core FDDI network via bridges, and allows for the transfer of data between the Core system (SDPs, MPACs and MSUs) and the Payload system (SDP, MSU, or Gateway).

A.6. Data Interface(s) Connectivity

The architecture of SDPs, MPACs, MSUs, MDMs and ORUs are interconnected via the FDDI, Mil-Std 1553B or RS-422 interface connections. In most cases redundant strings connect the devices along the Space Station, with many connections and multiple bus runs. All devices contain some interface adapter hardware and software for data transfer.

MDMs are located throughout the Station structure, modules, elements, and subsystems. To accommodate the many sensors and end effectors, connections to the DMS network is via 1553B serial bus interfaces. To accommodate those MDMs located outside the Alpha joint, which rotates to position the solar arrays, electronic roll rings embedded in the alpha joint hardware provide a continuous signal connection. Both MDM 1553B serial interface signals and MDM I/O analog signals are accommodated across this rotating joint as well as the main power buses.

The Beta joints for the solar arrays and for the thermal arrays accommodate sensor and effector signals in a similar manner to that used in the alpha joints.



Source: Reference 9.

Figure A-1. SSF Avionics Architecture.

Source: Presentation to SSSAAS, Dr. V. Whitelow, July 22, 1991.

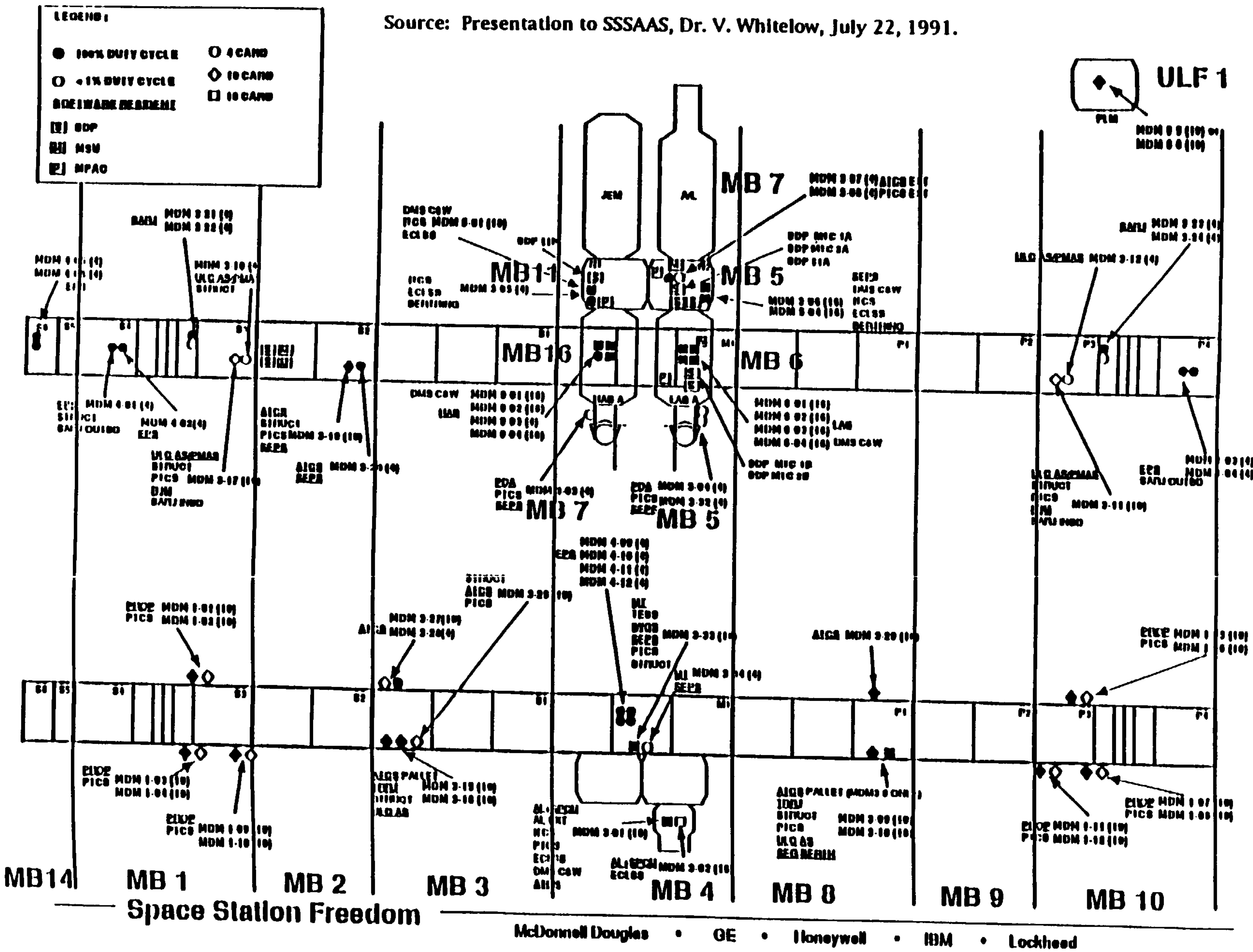
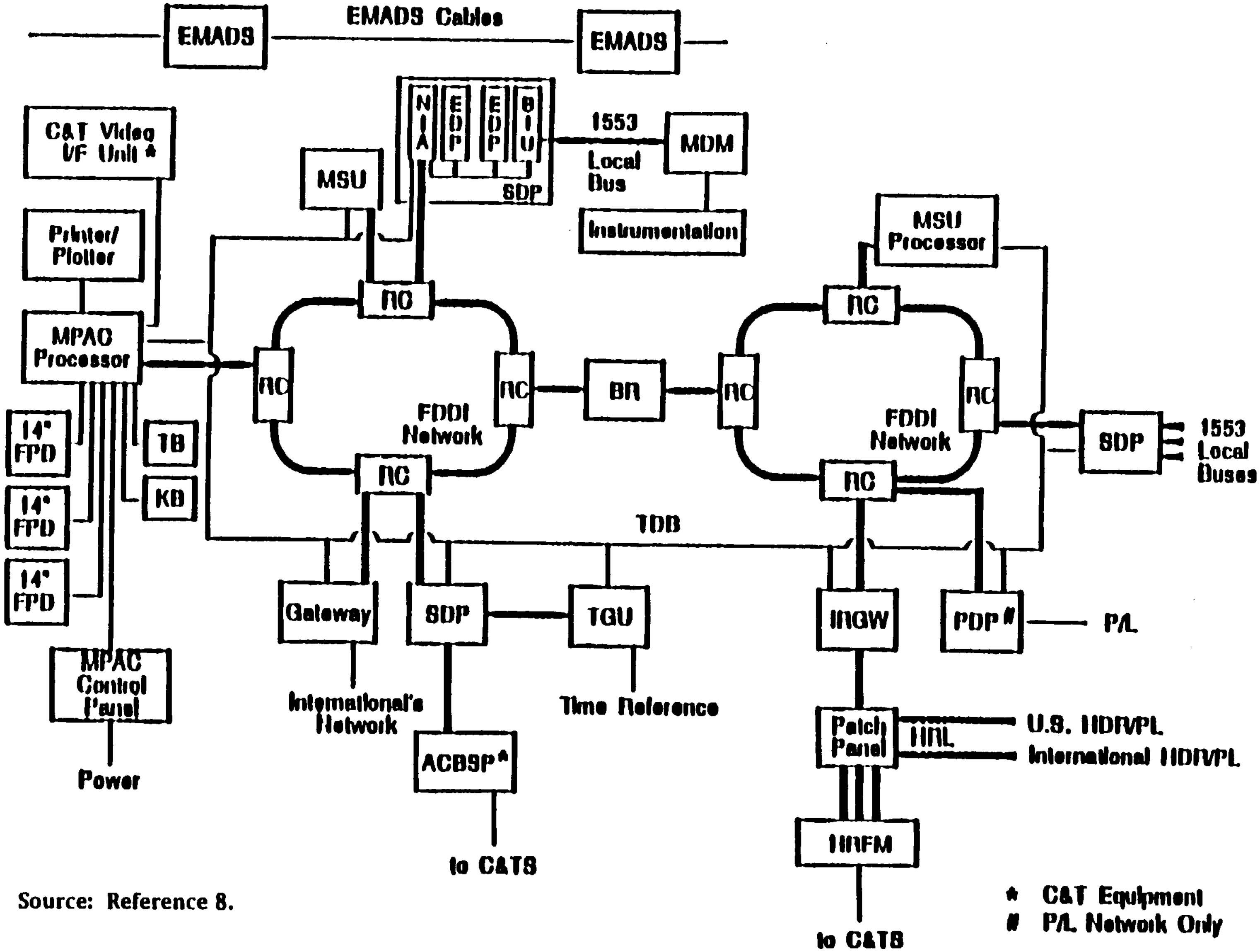


Figure A-2. SSF MDM Locations.



Source: Reference 8.

Figure A-3 . Major DMS System Components

APPENDIX B

MIE Software Interfaces

The Space Station Freedom (SSF) Data Management System (DMS) provides the necessary data acquisition services required to support MIE. Additional software to accommodate the instrumentation beyond the WP-2 definition and interaction with the Station DMS is not defined. The selected MDMs to support MIE are "Station Core MDMs." The MIE accelerometers and signal conditioners are integrated into the core system. The Station instrumentation and software interaction of Tier 1, the Computer Software Configuration Items (CSCIs) and in particular the Structural Dynamics Measurement System (SDMS) that support MIE tests are discussed in the following sections.

B.1 Tier 1

Tier 1 represents the SSF software system and DMS activities that are controlled and directed by the Station crew, Ground Control (e.g. MIE ground control) or the Integrated Station Executive (ISE) software. The DMS system is controlled by a set of Standard Data Processors (SDPs) that contain all software necessary for Station control and operation. Software resident in the SDPs is divided into CSCIs that are responsible for operations, control, and data transfers between station processors. Tier 1 embodies the range of capabilities and functions available to operators, ground control and on-line autonomous ISE software.

Tier 1 provides functionality for MIE and Station control through interaction with the Multi-Purpose Application Consoles (MPACs) used by crew members, the Control/Operations Centers (Ground), and the on-board resident ISE software. Figure B.1, shows the software interfaces.

Performing MIE will require interaction with ground control by receiving commands to start the experiment. Software functions within the core DMS SDPs will command the MDMs to perform sensor reads and data retrieval procedures.

B.2 Computer Software Configuration Item (CSCI) and the Structural Dynamics Measurement System (SDMS)

CSCIs reside in both the DMS SDPs and MDMs on-board the station, as well as residing in processor systems dedicated to Station ORUs. This section however, will focus on the CSCIs that provide the DMS functionality for the station (SDPS and MDMs).

The DMS SDPs are composed of multiple CSCI software sections. Each CSCI within the SDPs performs a particular function necessary for complete Station control and operation. Two particular CSCIs, DMS Standard Services (STSVC) and Data Storage and Retrieval (DSAR) are utilized to initiate an MDM to record or control sensors and effectors. Once initiated, the DMS SDPs receive MDM status and data reflecting the information required. The STSVC CSCI scans through a list of activities to perform and commands selected MDMs to perform certain functions. Then, the DSAR CSCI is responsible for receiving data from the MDM(s) and storing the data in either the Mass Storage Unit or for direct transmission to the ground.

The software CSCI in an MDM called the Structural Dynamics Measurement System (SDMS) is responsible for performing data gathering, data formatting (if any), and data transfers back to the SDPs. This SDMS software is the activity by which the baseline Station DMS manages the structural verification through MDM Input/Output (I/O) connections to effectors, strain gauges and accelerometers.

The MIE collects on orbit structural responses to externally applied vibrations, which are recorded by the MIE software. The MIE software is a modified version of the SDMS. It receives accelerometer data from the MDM I/O channels, and collects data for reporting to the ground via downlink services.

B.3. SDMS Interface To Tier 1

The SDMS CSCI interface to Tier 1 is used to pass MIE commands and parameters from Tier 1 (MIE ground) to the SDMS and to pass responses from SDMS to Tier 1, Table B.1. and Figure B.1. and B.2. The MIE software operates similarly.

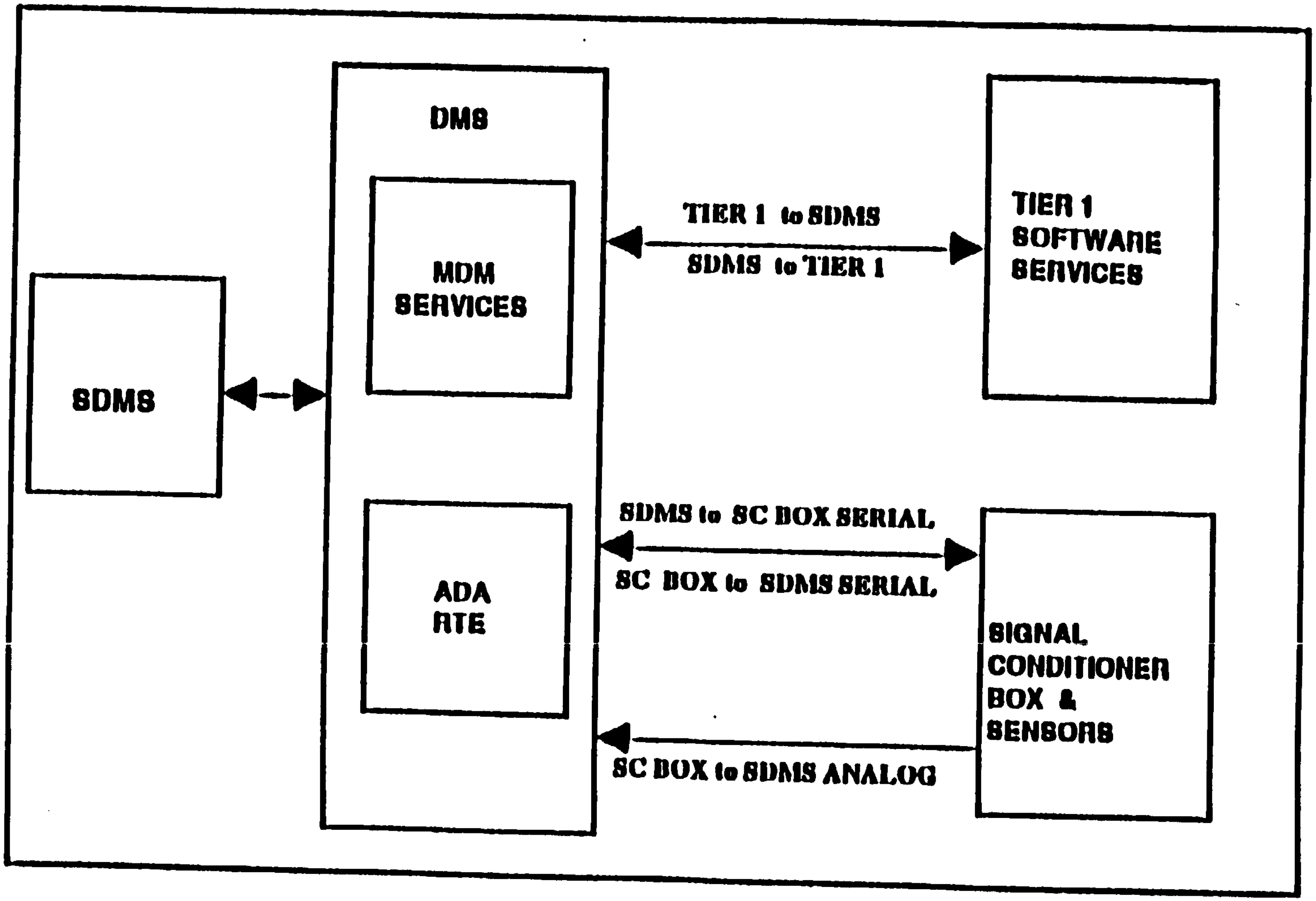
B.4. SDMS Interface To Signal Conditioner Box (SCB)

The SDMS CSCI interface to the SCB is through the MDM processor and I/O back plane. Analog accelerometer inputs from the SCB are routed to the standard I/O cards, which contain the Analog to Digital (A/D) converters. Access to the accelerometer data is provided by the MDM services/ADA Run Time Environment Services of Data Management Systems (DMS), which place the accelerometer values into the Input-Output Data Base (IODB). Accelerometer ranging commands are sent out to the SCB through a Serial Discrete Input-Output (SDIO) port on a Serial Parallel Digital 1553 card plugged into the MDM back plane, Figure B.3. The MIE on-orbit range options are 4.17, 12.5, 33 and 100 milli G's.

Name	Description	Interface Type
Tier 1 To SDMS	The interface from Tier 1 to the SDMS CSCI. It is used to pass commands and parameters to SDMS.	Software
SDMS To Tier 1	The interface from the SDMS CSCI to Tier 1. It is used to pass command responses and statuses to Tier 1.	Software
SDMS to Signal Box	This interface is used to send signal ranging to the signal conditioner box. It passes through the MDM SX or User Back plane.	Software
Signal Box to SDMS	This interface is used to obtain sensor values. The sensor values are obtained by I/O lists through the IODB.	Software

Source: Reference 7.

Table B-1. SDMS CSCI External Interfaces.



Source: Reference 7.

Figure B-1. SDMS Interface to Tier 1.

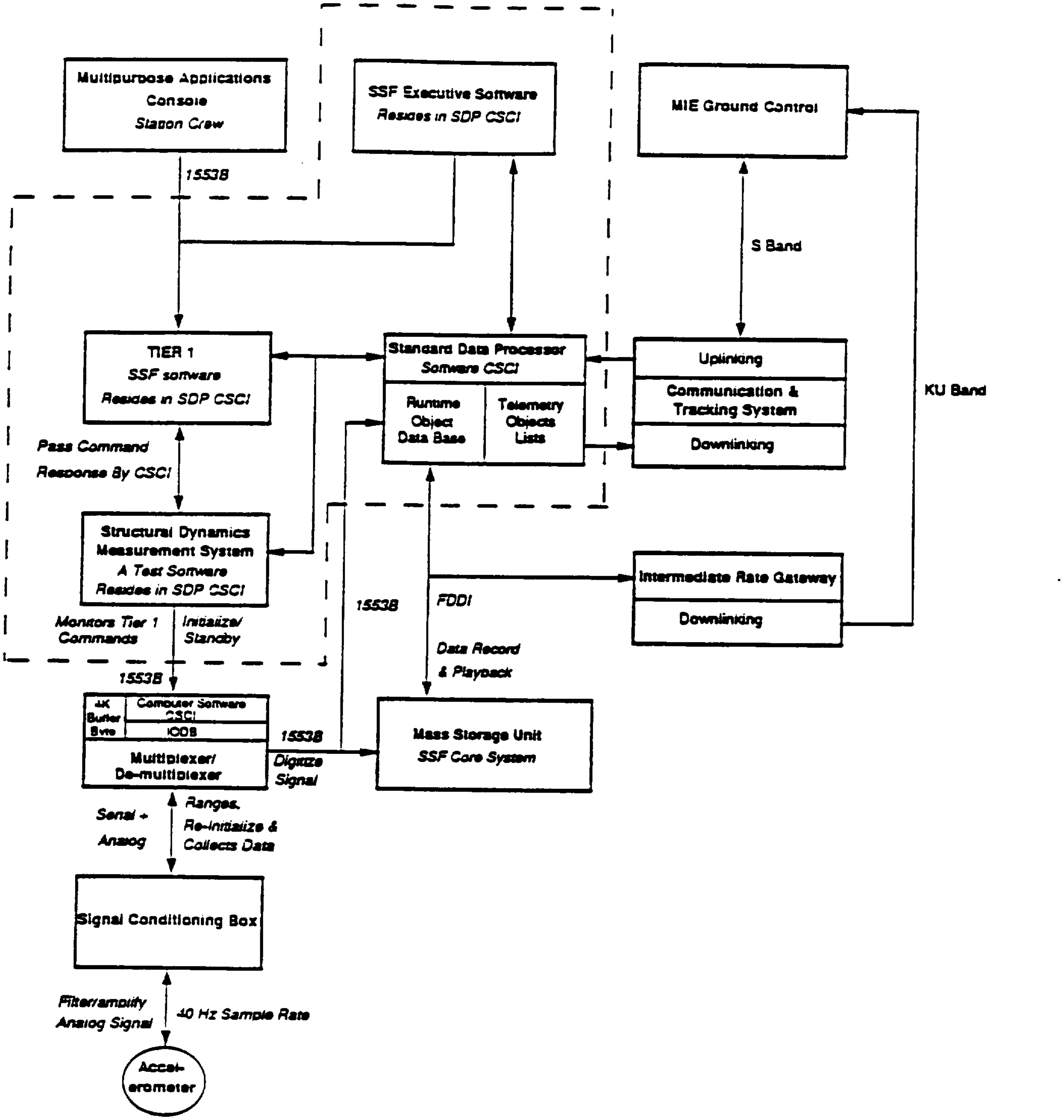
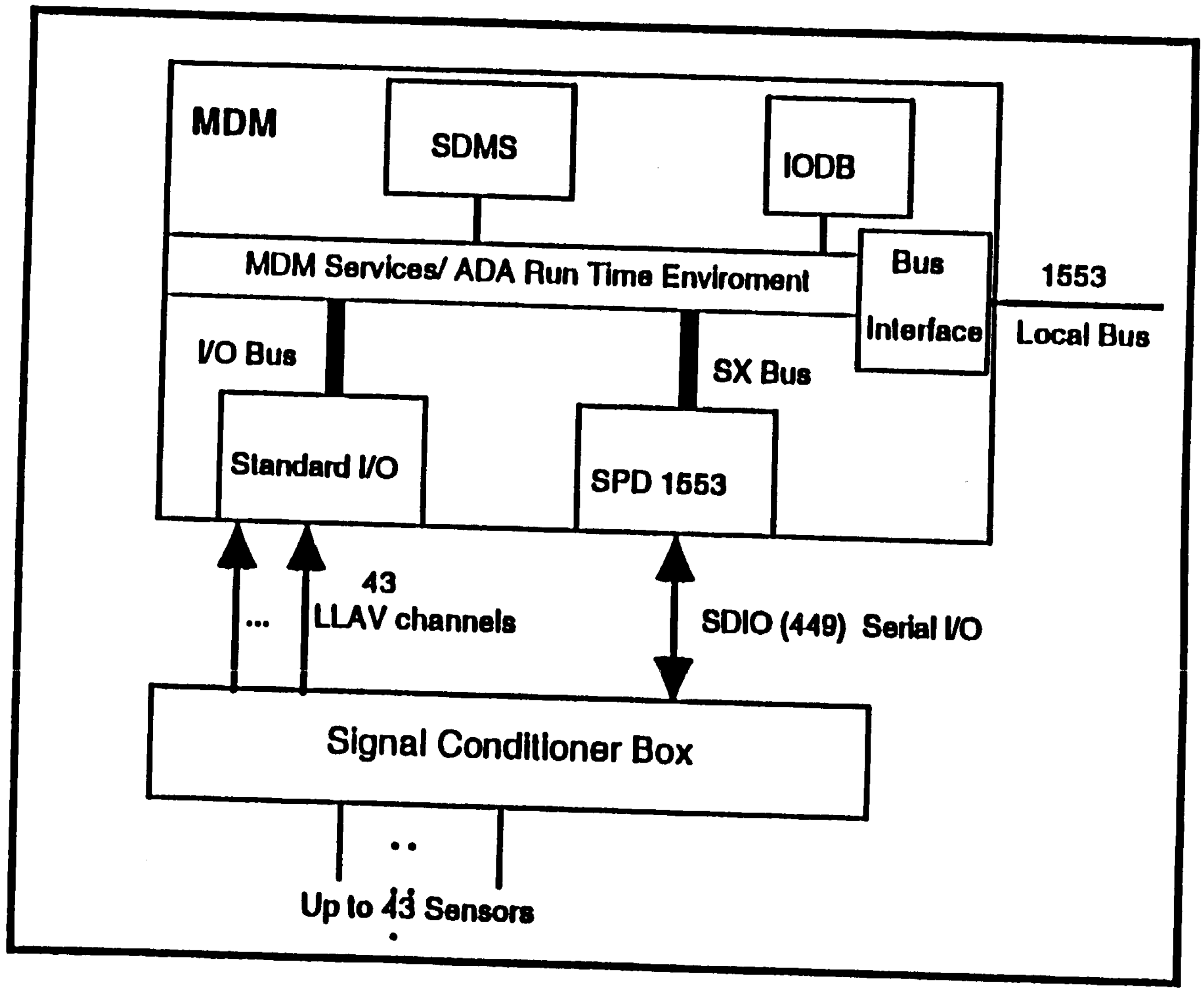


Figure B-2. MIE Operational Interfaces.



Source: Reference 7.

Figure B-3. SDMS Interfaces-Block Diagram.

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13. ABSTRACT (Maximum 200 words)

The Modal Identification Experiment (MIE) will monitor the structure of the Space Station Freedom (SSF), and measure its response to a sequence of induced disturbances. The MIE will determine the frequency, damping, and shape of the important modes during the SSF assembly sequence including the Permanently Manned Configuration. This paper decribes the accommodations for the proposed instrumentation, the data processing hardware, and the communications data rates. An overview of the MIE operational modes for measuring SSF acceleration forces with accelerometers is presented. The SSF instrumentation channel allocations and the Data Management System (DMS) services required for MIE are also discussed.

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Modal Identification Experiment, MIE, accelerometer, accommodation, architecture, data management, data rates, instrumentation, interface, modes, operation, software, Space Station Freedom.

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